MSC-23314-1 Patent Application

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

#9/ Declaration 1-28-03

In re Application of: Christiansen et al. §
§ Examiner: Jordan M. Lofdahl
Serial No.: 09/892,355 §
§ Group Field Unit: 3644
Filed: June 26, 2001 §
§
Title: Flexible Multi-Shock Shield §

Commissioner for Patents
Washington, D.C. 20231

CERTIFICATE OF MAILING UNDER 37 C.F.R. §1.8(a)
I hereby certify that this correspondence is being deposited with the U.S. Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, Washington, D.C. 20231, on
December 20, 2002
By: James M Cate
Signature: James M Cate

Dear Sir:

DECLARATION UNDER 37 C.F.R. § 1.132

I, Eric L. Christiansen, hereby declare:

1. I am at least 18 years of age and am competent in all respects to make the following statements.

2. I live at 1410 New Cedars, Houston, TX 77062.

3. I am one of the inventors listed in the above application for U.S. patent, serial no. 09/892,355, entitled "Flexible Multi-Shock Shield."

4. I have a Bachelors Degree in Chemical Engineering from Purdue University; a Masters Degree in Materials Engineering from Purdue University; and a Doctorate in Mechanical Engineering from the Technical University of Munich. I am a member of the American Institute of Aeronautics and Astronautics, on the Board of Directors of the Hypervelocity Impact Society, and a Registered Professional Engineer in the State of Texas (License No. 70451). For 13 years, I have

specialized in the field of hypervelocity impact science and technology development. I have authored or co-authored over 60 technical articles, and I am a co-inventor of U.S. Patent No. 5,610,363, entitled "Enhanced Whipple Shield." My Biography is attached.

5. I have reviewed U.S. Patent No. 6,298,765 (Dvorak), entitled "Multi-shock Assembly for Protecting a Spacecraft Surface From Hypervelocity Impactors." In my opinion, the Dvorak patent does not provide sufficient information for a person of ordinary skill in my field to practice the invention described therein. I hold this opinion because (a) there is no teaching in the patent to instruct a person of ordinary skill in this field regarding the amount of shielding that would be needed to effectively protect a spacecraft surface from failure caused by impact with meteoroid and orbital debris of a particular size and density; and (b) there is no definition in the patent of the protection afforded by the "spacecraft surface" itself, thereby making it nearly impossible to apply the multi-shock shielding concept described in the patent with any degree of assurance that the shield will fulfill its intended function (i.e., to provide protection from meteoroid and orbital debris impact).

Regarding the first point, a spacecraft shielding system typically is designed to provide a required reliability level expressed as the probability of no penetration (PNP). PNP is inversely related statistically to the area of the spacecraft (A), duration exposed to the threat (t), and the "flux" or number of meteoroid and debris particles that can fail (i.e., completely penetrate) the shield per spacecraft surface area over time (F). Mathematically, PNP can be expressed as:

$$PNP = e^{-F \cdot A \cdot t}$$

The flux of particles is inversely proportional to the particle size that the shield can stop (or protect against). That is, as shielding capability increases, the particle size the shield can stop increases, the flux of particles decreases, and spacecraft reliability in terms of PNP increases. To

properly design a multi-shock shield to meet the required level of reliability, one must be able to mathematically relate the shielding materials, layer thicknesses, and distances or spacing between the layers with particle size that can be "stopped." These mathematical relationships or equations must be developed from detailed analyses and hypervelocity impact tests during development of the shielding. The equations are unique for a given type of spacecraft material, shielding and component configuration. It can be appreciated that spacecraft reliability and crew safety depend on establishing sufficient shielding to meet PNP requirements, which requires accurate assessment of the thickness, materials, and spacings between layers of the shielding component parts that are necessary to meet a given PNP requirement. However, it should also be apparent, that over protecting a spacecraft (i.e., an "over-kill" solution) is extremely detrimental as launch costs are typically expressed in thousands to tens of thousands of dollars per kilogram mass launched to orbit. Another point to consider is that any mass allocated to spacecraft meteoroid/debris shielding can not be allocated to other purposes which are the very reason for the space mission in the first place (e.g., science equipment, payloads, etc.). Therefore there is a delicate balance between sufficient shielding mass to meet reliability requirements, but not too much shielding with corresponding significant reduction in spacecraft payload lift capability. It is absolutely essential to define the appropriate mathematical relationships to be used for design purposes to make a given shielding concept applicable in practice.

Regarding the second point, in order to design an effective multi-shock shield, a person of ordinary skill in my field must be able to precisely relate the amount of protection provided by the spacecraft surface itself to the multi-shock shield. By way of a simplistic example, if the spacecraft surface can provide a certain level of protection that, when combined with the multi-shock shield, is adequate to protect the spacecraft, then less shielding may be needed. On the other hand, if the

spacecraft surface provides little or no protection, then a final layer, such as a back wall, must be provided in the multi-shock shield to guarantee adequate protection. In addition, the thickness of the back wall and the type of materials used are also factors that must be taken into account in terms of their effect on the multi-shock shield.

The Dvorak patent fails to define any of the relationships discussed above. Without knowing the proper relationship between the various layers of the multi-shock shield and the particles to be shielded against, a person of ordinary skill in this field would not be able to design an effective shield for particles of a given size. The Dvorak patent also fails to provide information about the necessity of including a back wall to meet protection requirements, or that the back wall may be different in thickness and material type from the preceding disrupting/shocking (shield) layers. Therefore, for at least the stated reasons, the Dvorak patent does not enable a person of ordinary skill in my field to practice the hypervelocity, multi-shock shield described therein with any reasonable assurance that the shield will meet protection requirements when applied to an actual spacecraft in space.

6. On the other hand, the present application does define the relationship between the various components of the shield relative to the size and density of the particles that are expected to impact the shield. These relationships are defined in Equations 1-5 of the application. Specifically, Equations 1-2 define the proper relationship between the various components of the shield from a design point of view. Note that the areal density of the shield layers, m_b (g/cm^2), is equivalent to the product of the shield layer thickness (cm) and density (g/cm^3) summed over all shield layers. Similarly, the areal density of the back wall, m_w (g/cm^2), is equal to the product of back wall thickness (cm) and density (g/cm^3). Equations 3-5 are used to assess the performance in terms of

particle size stopped (or defeated) by a hypervelocity, multi-shock shield as a function of particle velocity, impact angle and density. These equations relate the shielding materials, layer thickness, and spacing between the layers with the particle size that can be "stopped" and, therefore, would enable a person of ordinary skill in this field to properly design a hypervelocity, multi-shock shield for a given size particle and reliability level. In addition, the equations in the present application show that the back wall **32** can differ significantly in thickness and material type from the shield layers **20**. Furthermore, the present application specifically indicates that Kevlar® will (along with Spectra® and other high-strength fabric materials) make suitable back wall materials.

7. The relationships embodied in Equations 1-5 of the present application are not known to, or readily derivable by, a person of ordinary skill in this field. These equations have been developed and verified based on a considerable amount of data from numerous hypervelocity impact tests and theoretical studies over a period of 15 years at enormous expense to the assignee of the application. And while there are literally hundreds of hypervelocity impact shielding equations in the literature (see, e.g., U.S. Patent No. 5,610,363), a person of ordinary skill in my field would not be able to select the appropriate equations to use to apply to the particular multi-shock design disclosed in the Dvorak patent and arrive at a shield design that will meet protection requirements.

8. I declare further that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are

punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such false statements may jeopardize the validity of the application or any patent issuing thereon. Executed on 20 December, 2002.

Eric L. Christiansen